
Biomimetic Acoustic Sensors

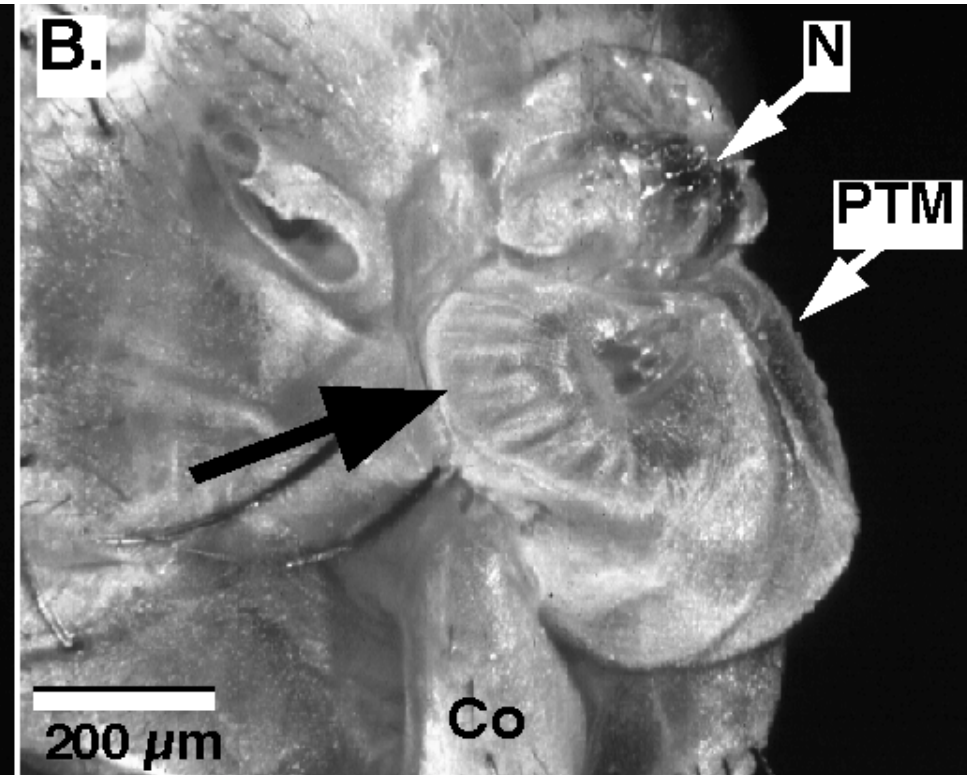
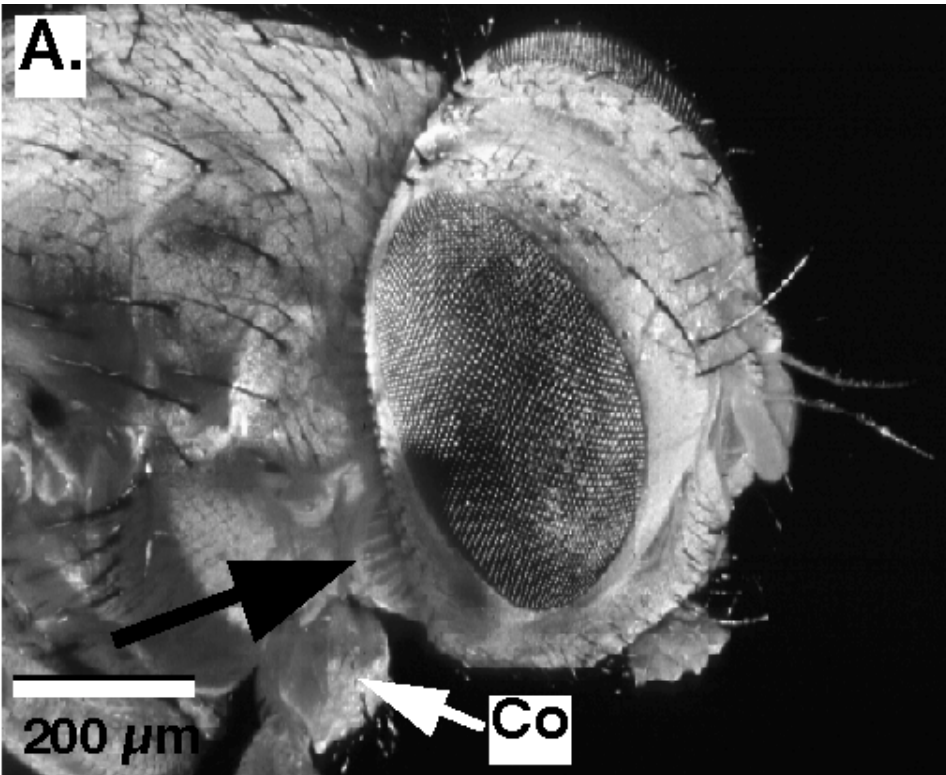
Ronald N. Miles
Department of Mechanical Engineering
State University of New York
Binghamton, NY

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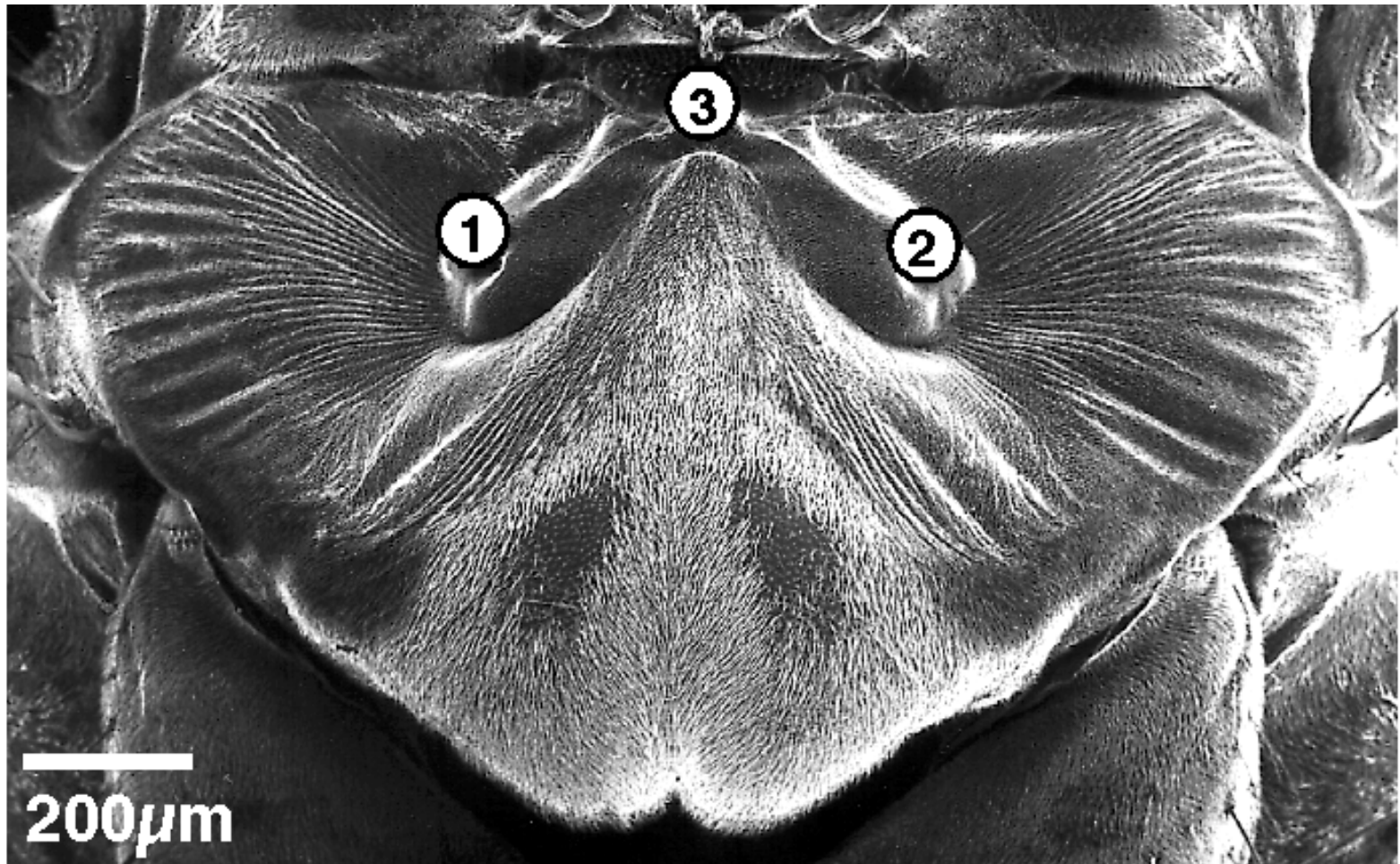
Outline

- Mechanically coupled ears in a parasitoid fly:
Novel mechanism for directional hearing
 - Biomimetic microphone for hearing aids
 - Directional vibration sensing in a treehopper
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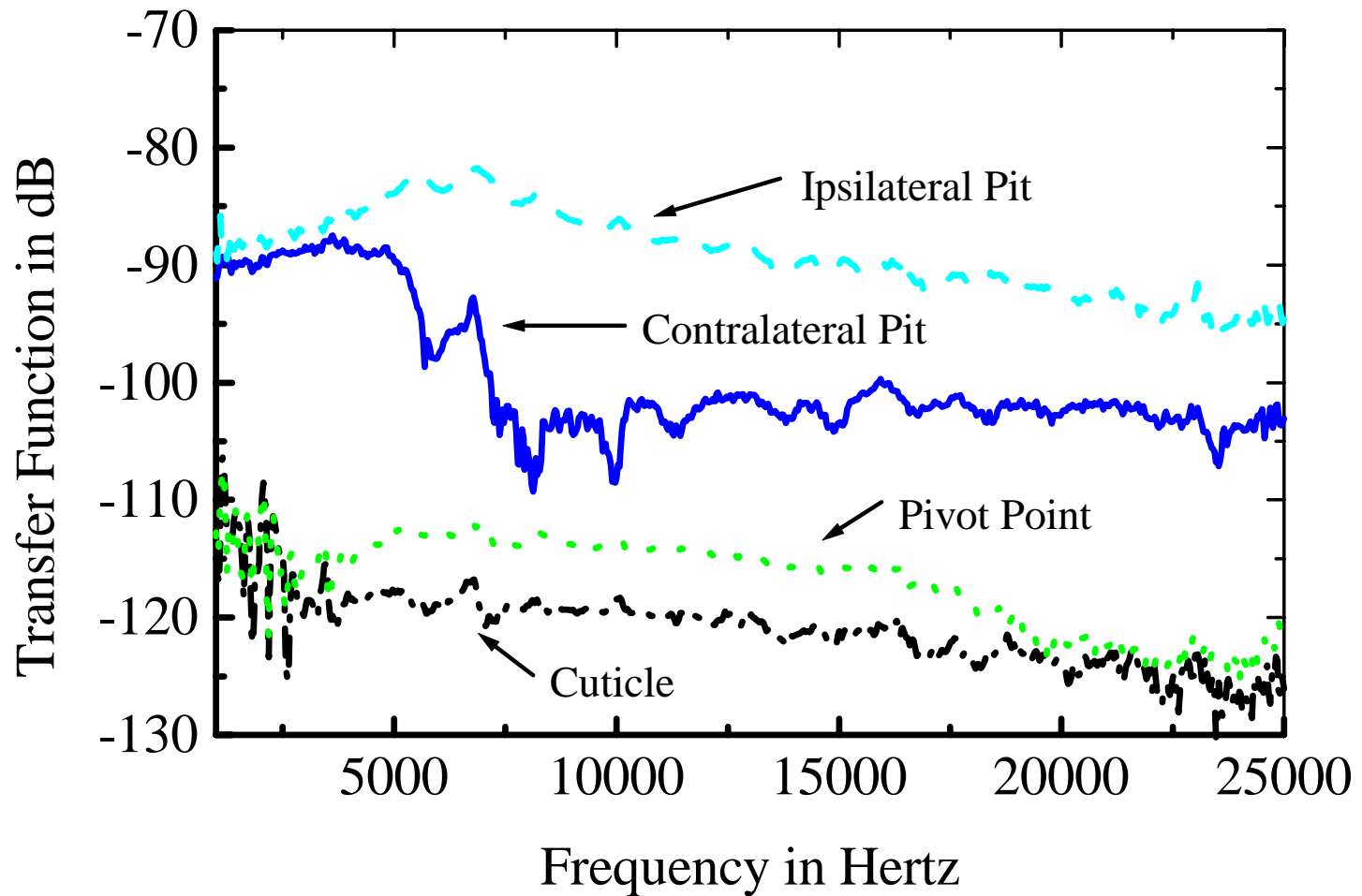
External Anatomy of the Fly's Ears



External Anatomy of the Fly's Ears

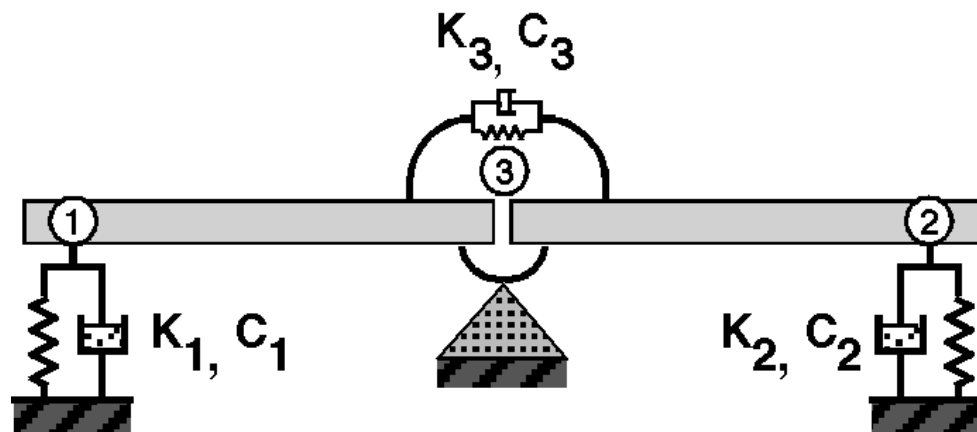
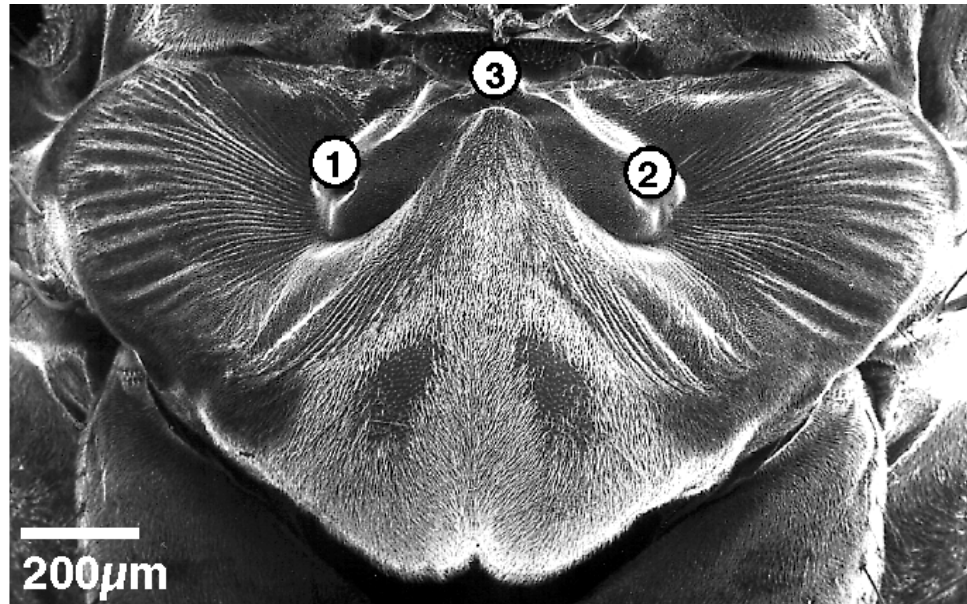


Measured Response is Highly Directional



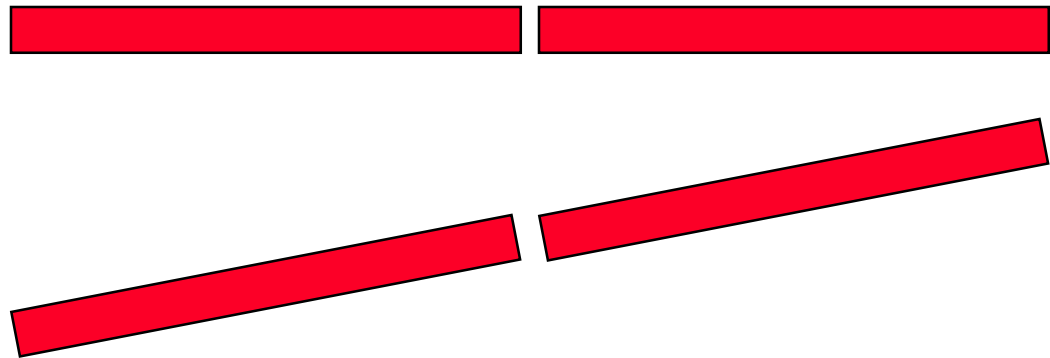
Female Ear Response

Mechanical Model of the Fly's Ears

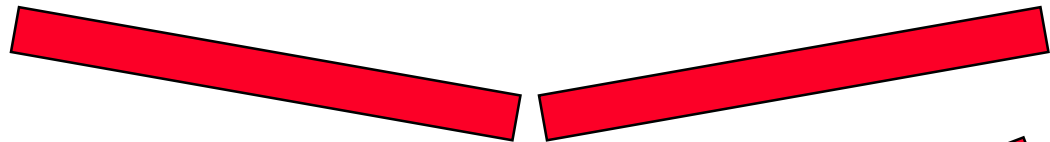


Highly Directional Two-Mode Sensor

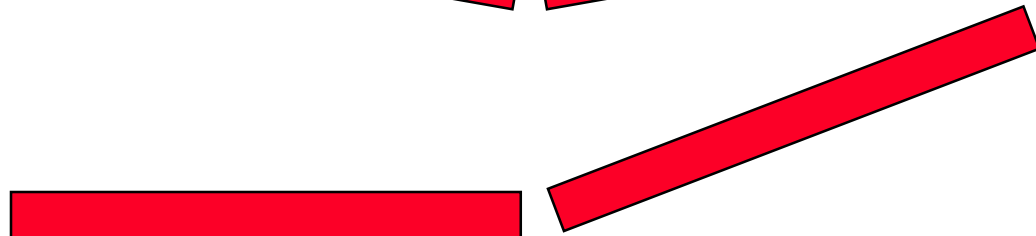
Anti-symmetric
mode



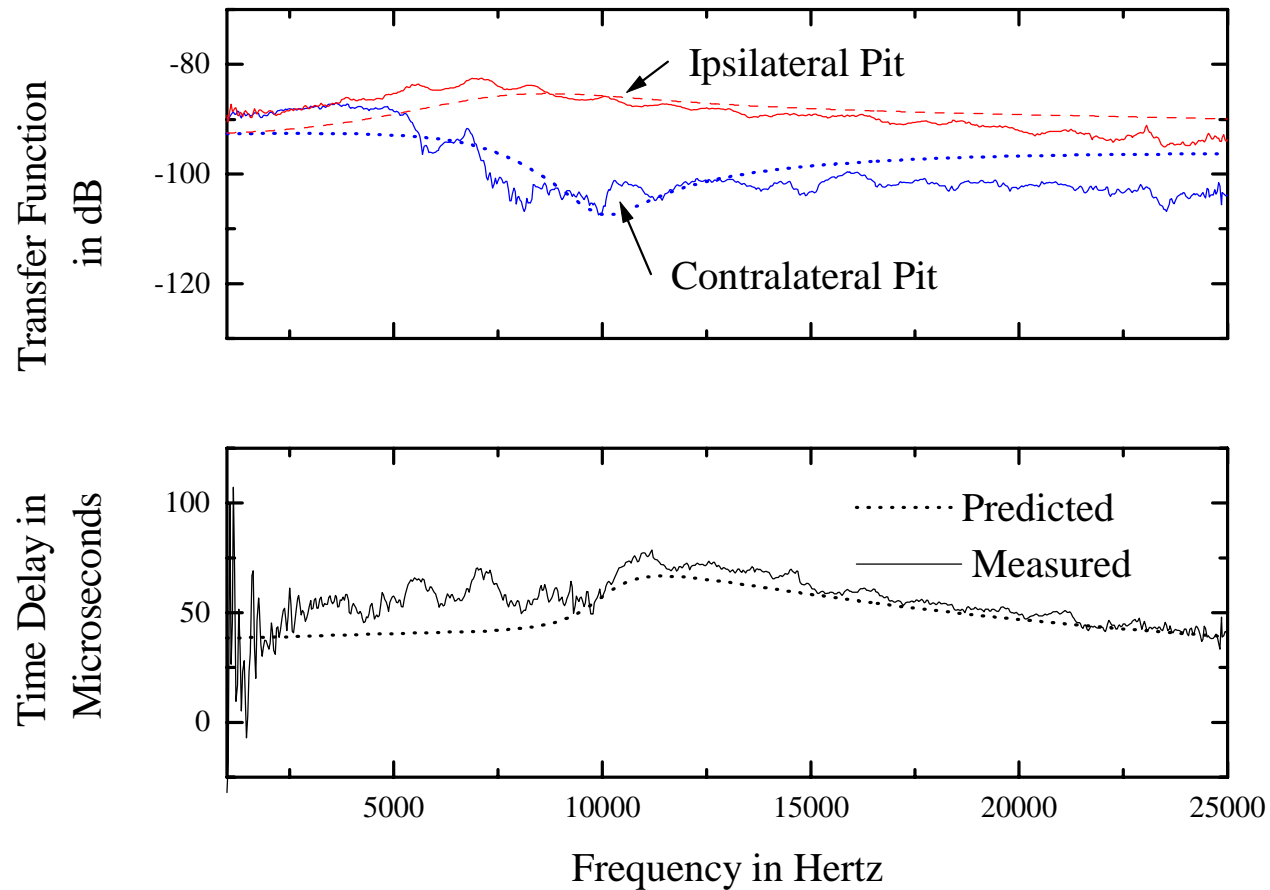
Symmetric
mode



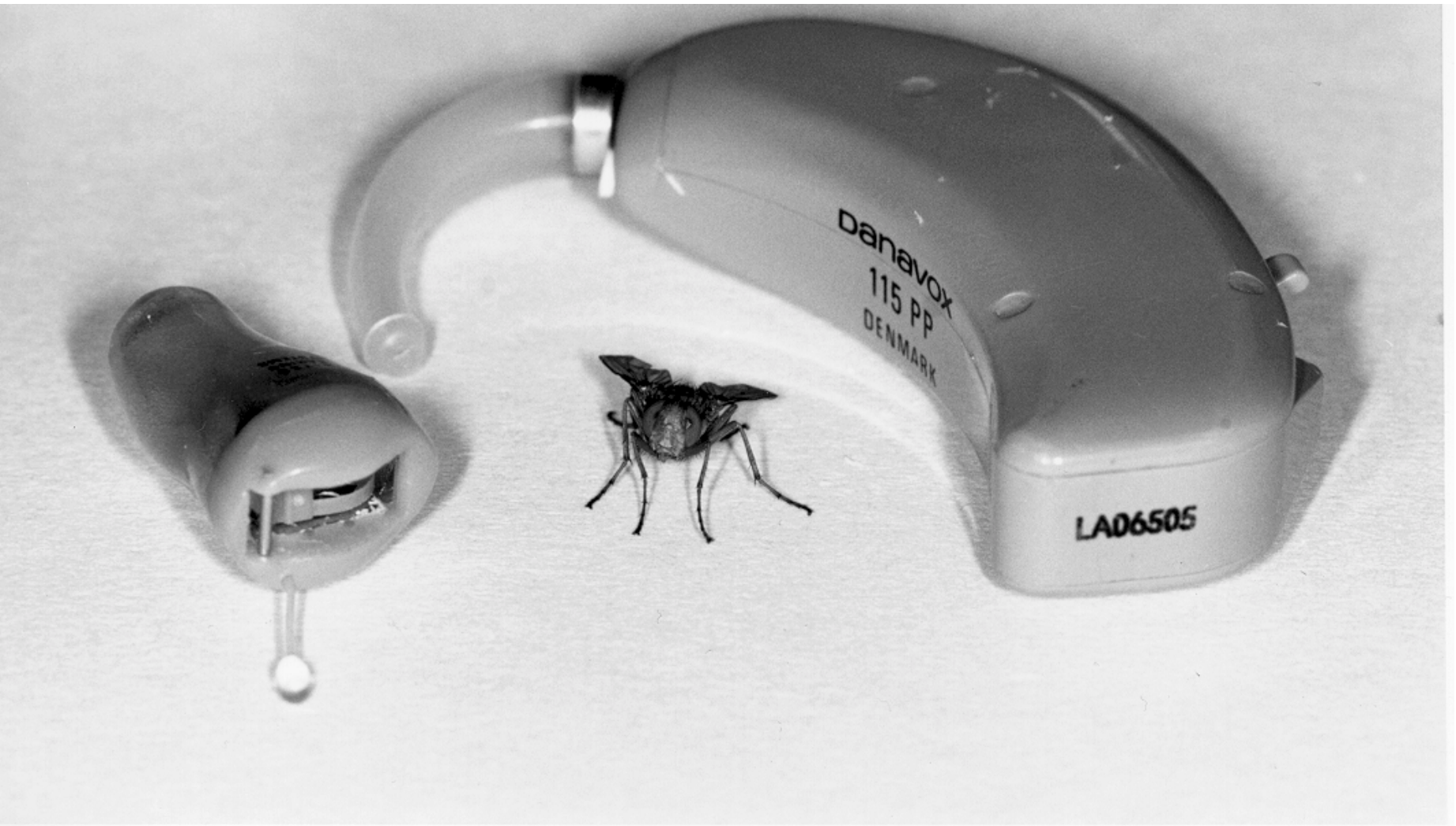
Combined
response



Analytical Model Predicts Ear's Response



Application: Directional Hearing Aid Microphone



Etymotic D-Mic

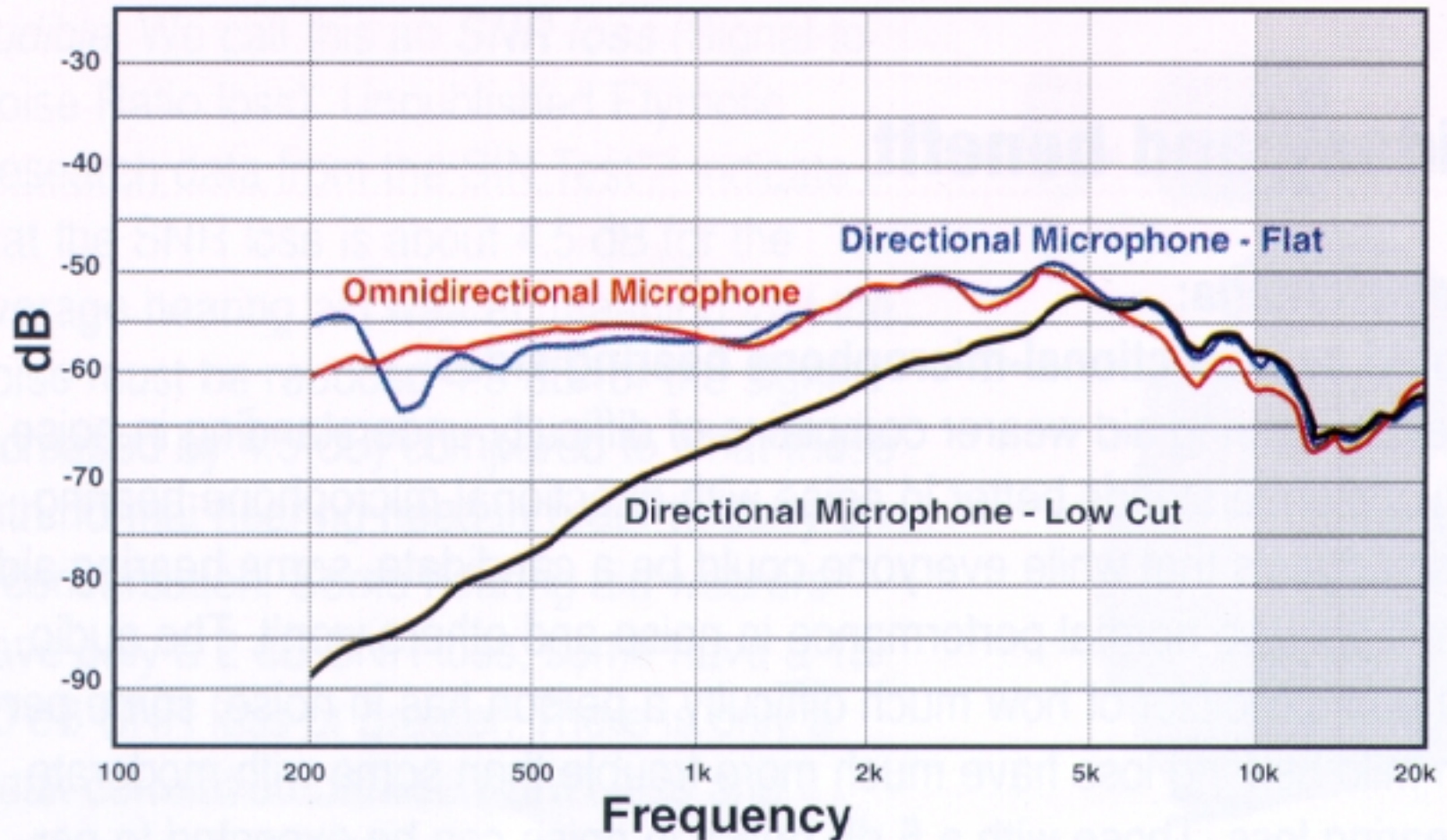


ETYMOTIC  RESEARCH

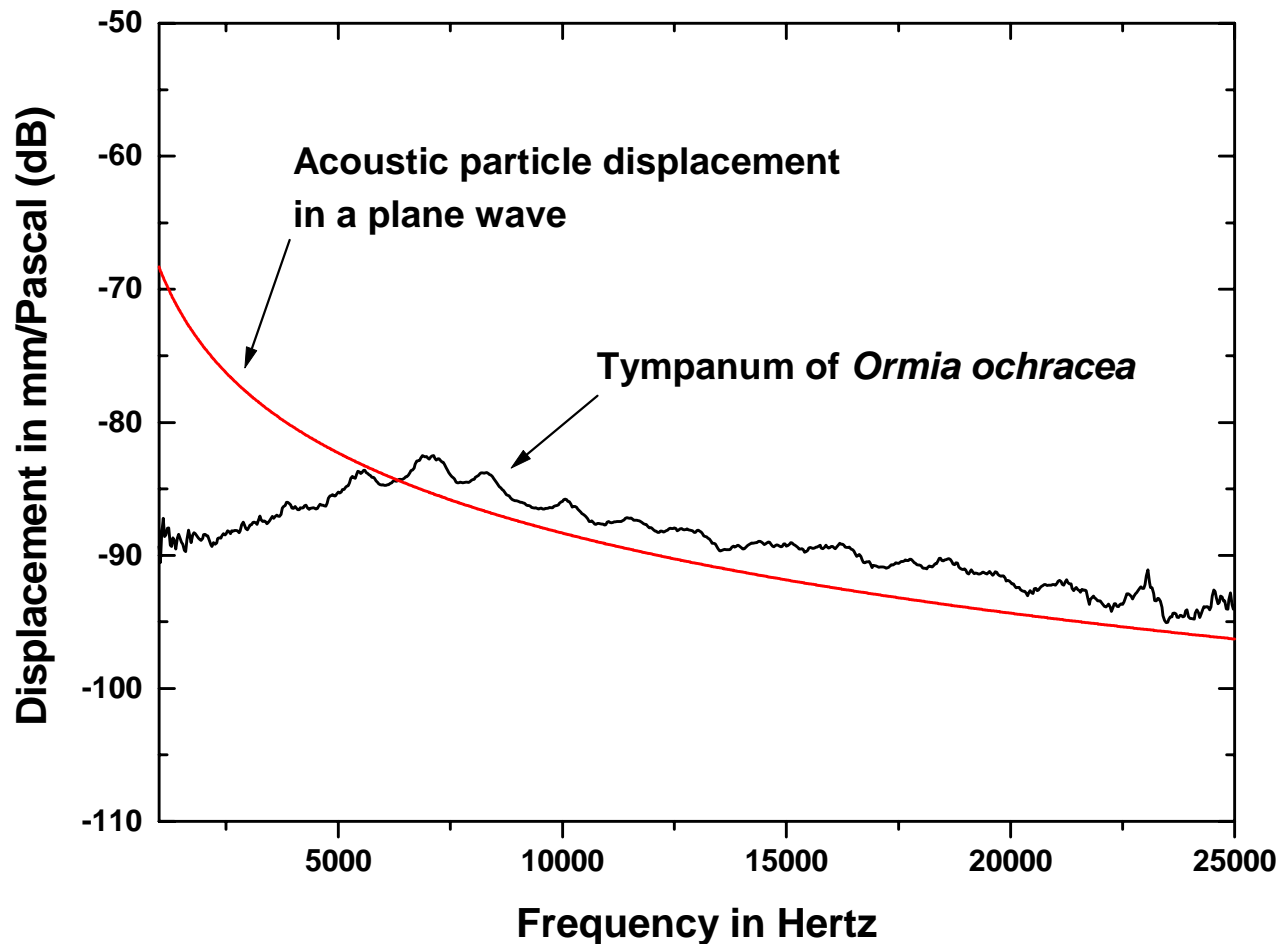


Measured Response of D-Mic

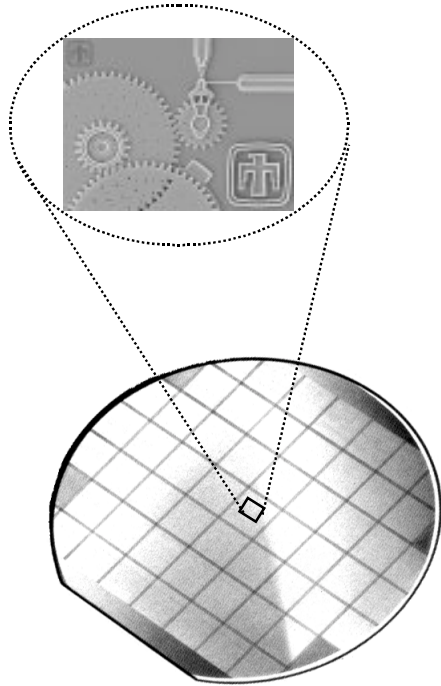
FREQUENCY RESPONSE (KEMAR)



The Fly's Ear is a Sensitive Acoustic Sensor



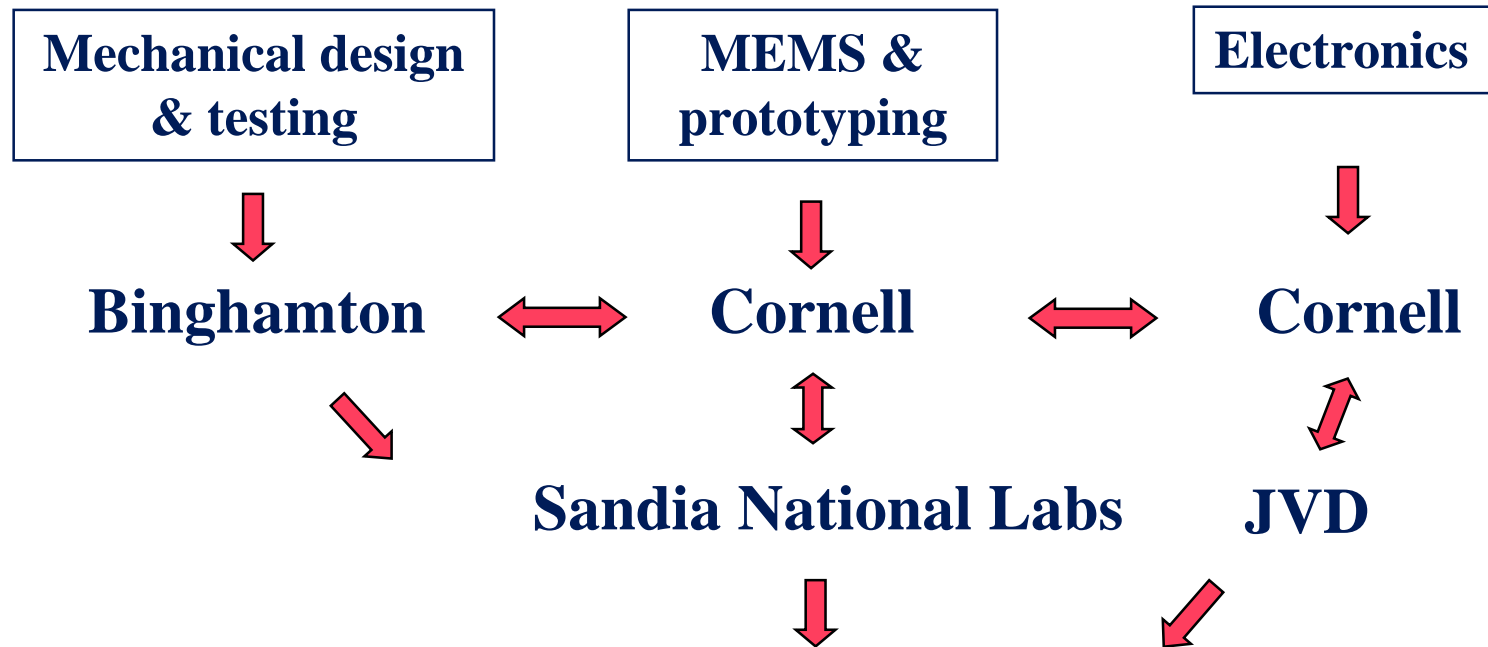
MEMS



- **Microelectromechanical systems**
- **Mechanical devices with integrated circuits on silicon**
- **Batch fabrication using silicon IC technology**
- **New solutions that are low-cost**

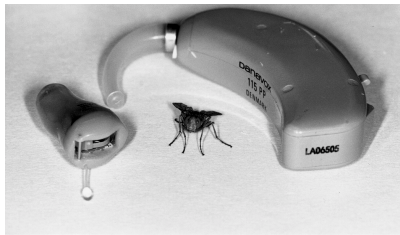
✳ **Can implement the fly's ear in a hearing aid using silicon MEMS technology**

Team Organization



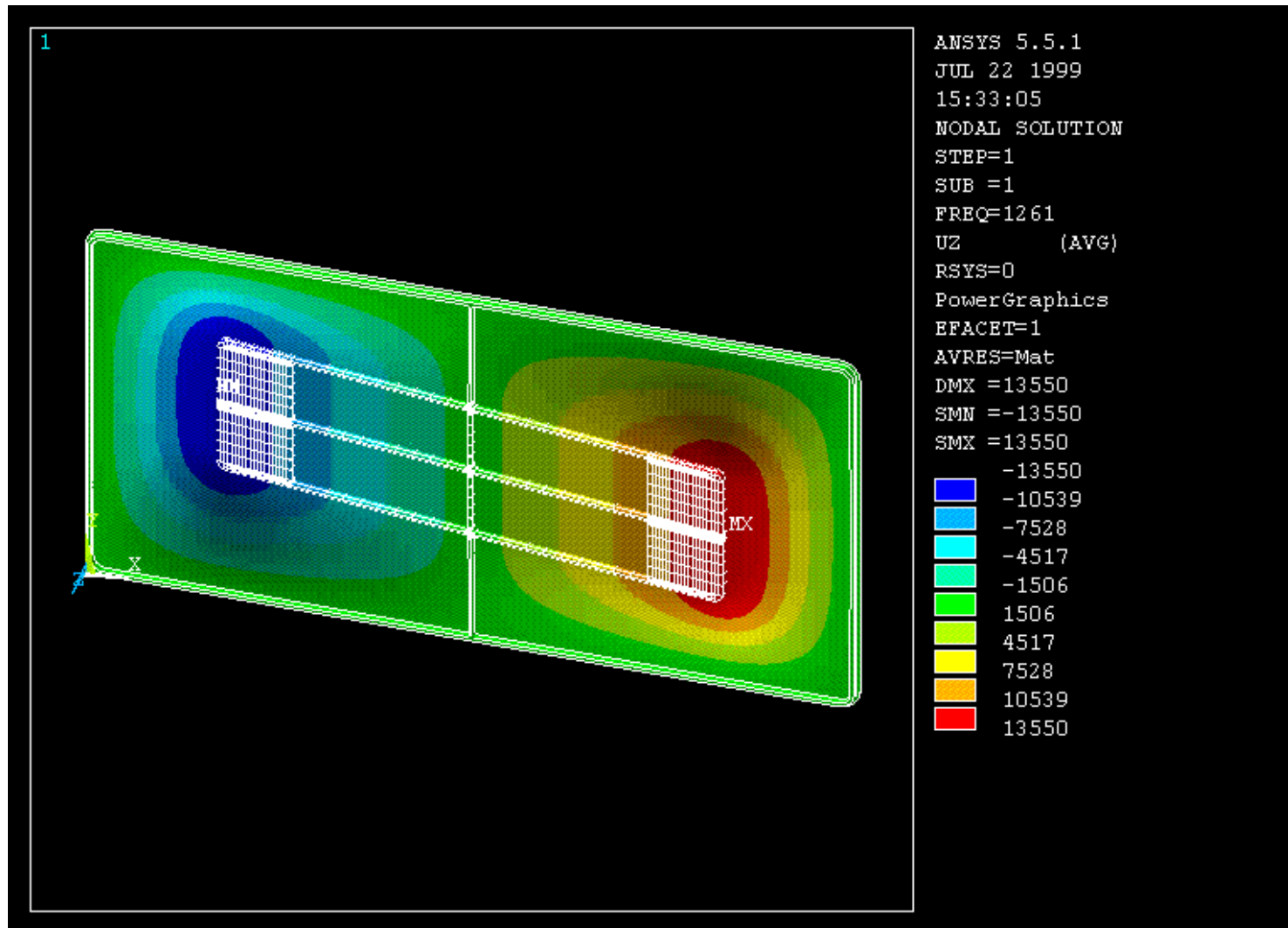
Consultants:

Bob Young
Ron Hoy

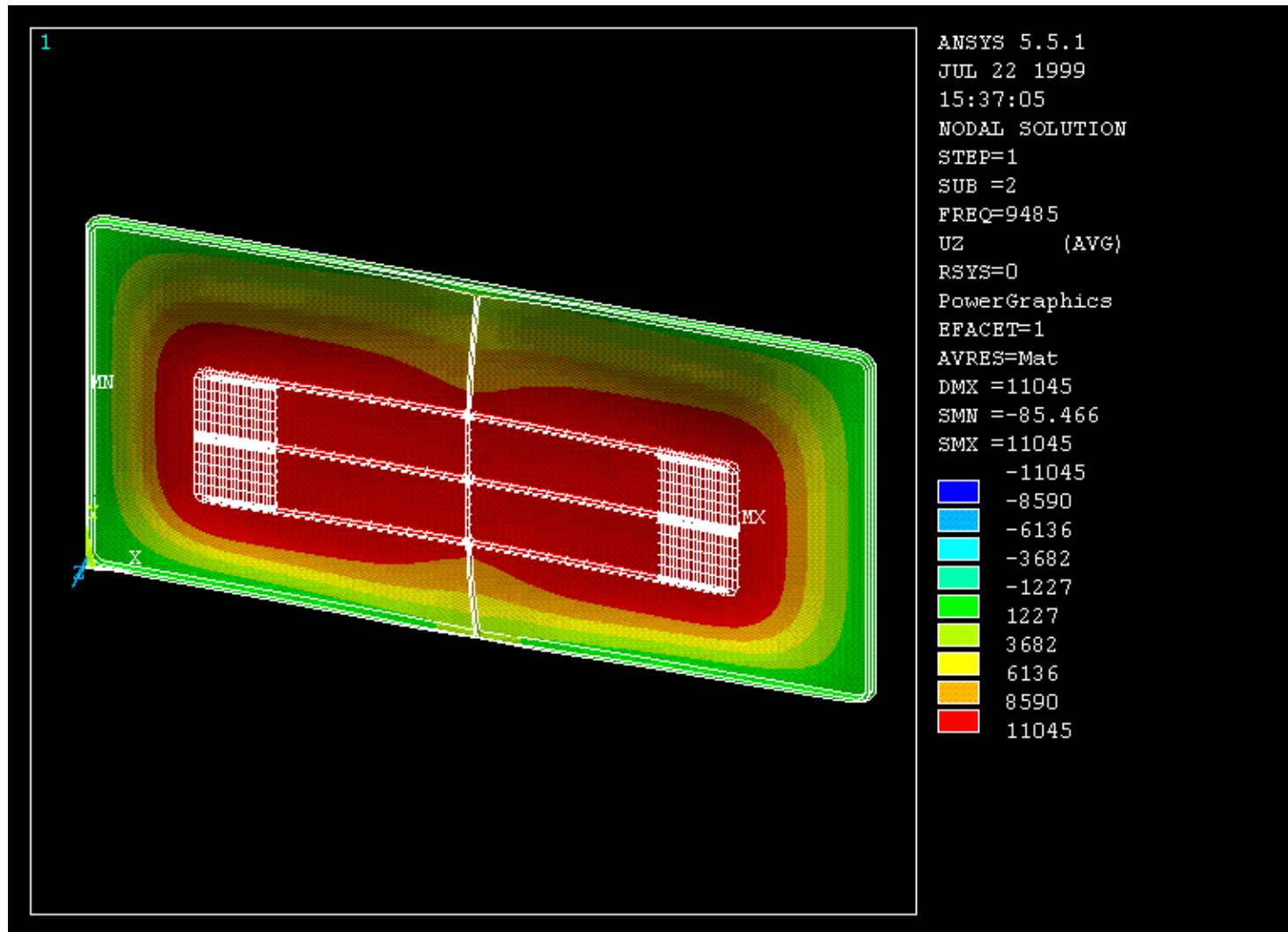


Toward commercialization

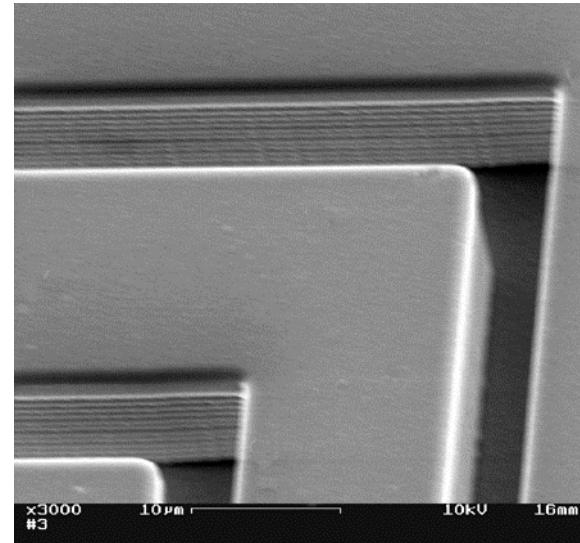
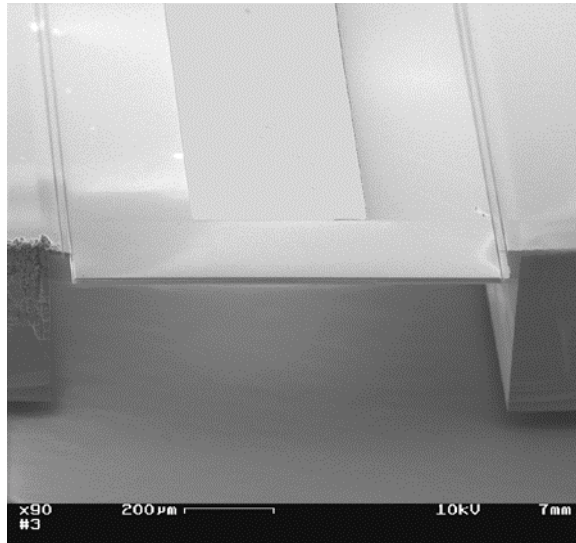
Membrane Design using FEM



Membrane Design using FEM



Polysilicon membranes



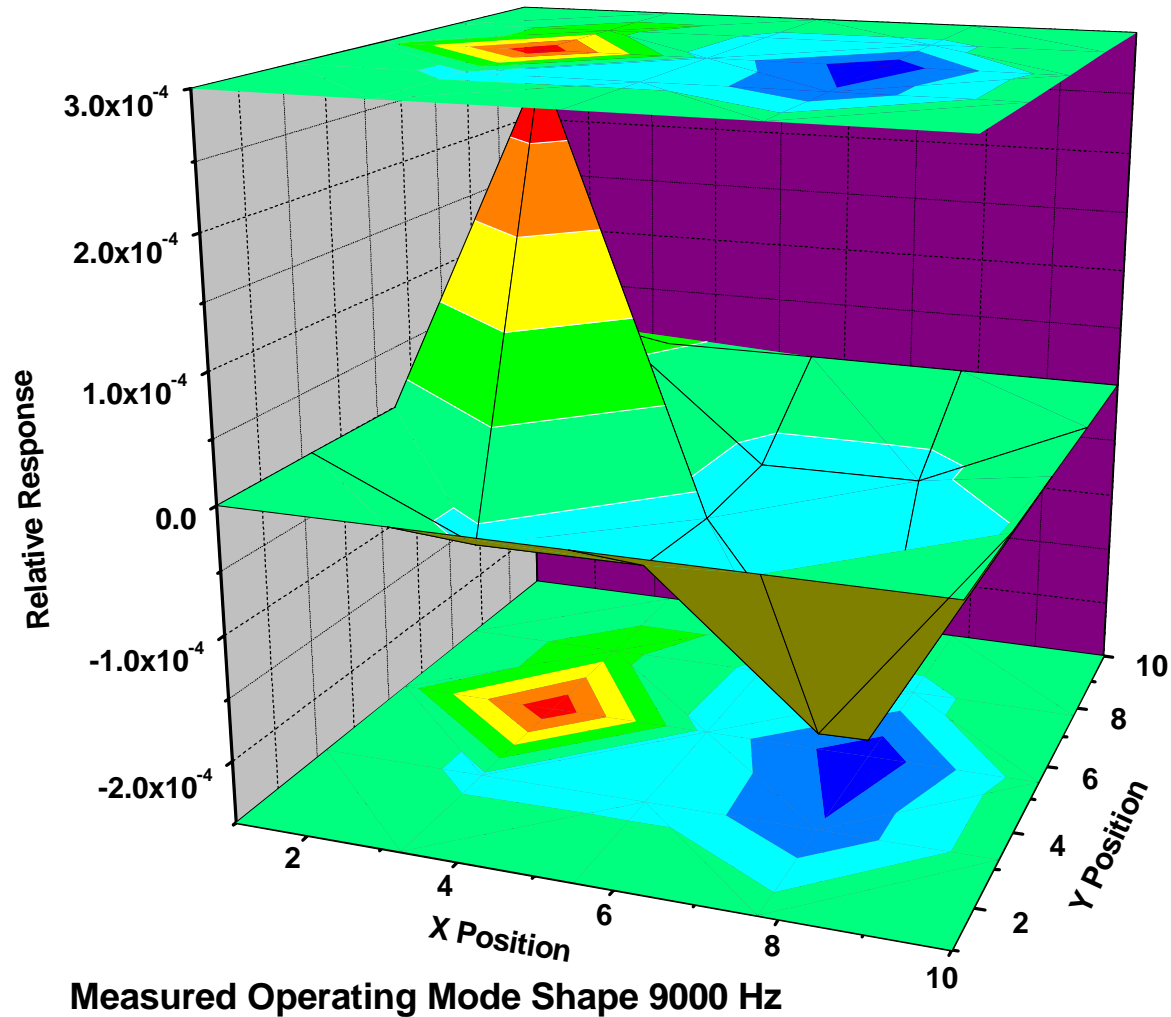
Close-up of the corrugation

Cross-section of the 1.0 x 0.5 mm² polysilicon membrane. The membrane is 0.5 μm thick with 10 μm deep corrugations.

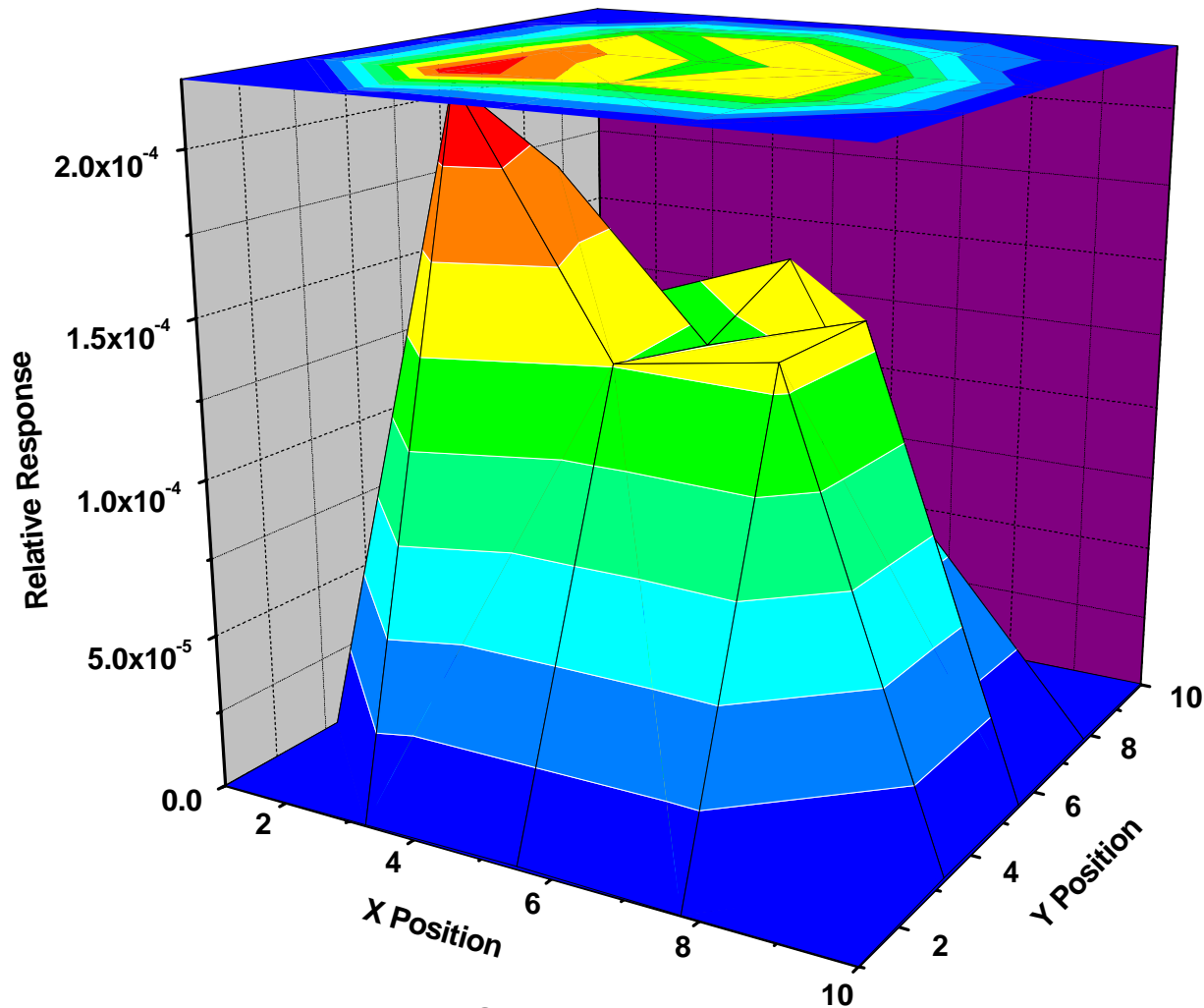
Measurement of Mechanical Sensitivity



Measured Anti-symmetric Mode



Measured Symmetric Mode



Measured Operating Mode Shape 13063 Hz

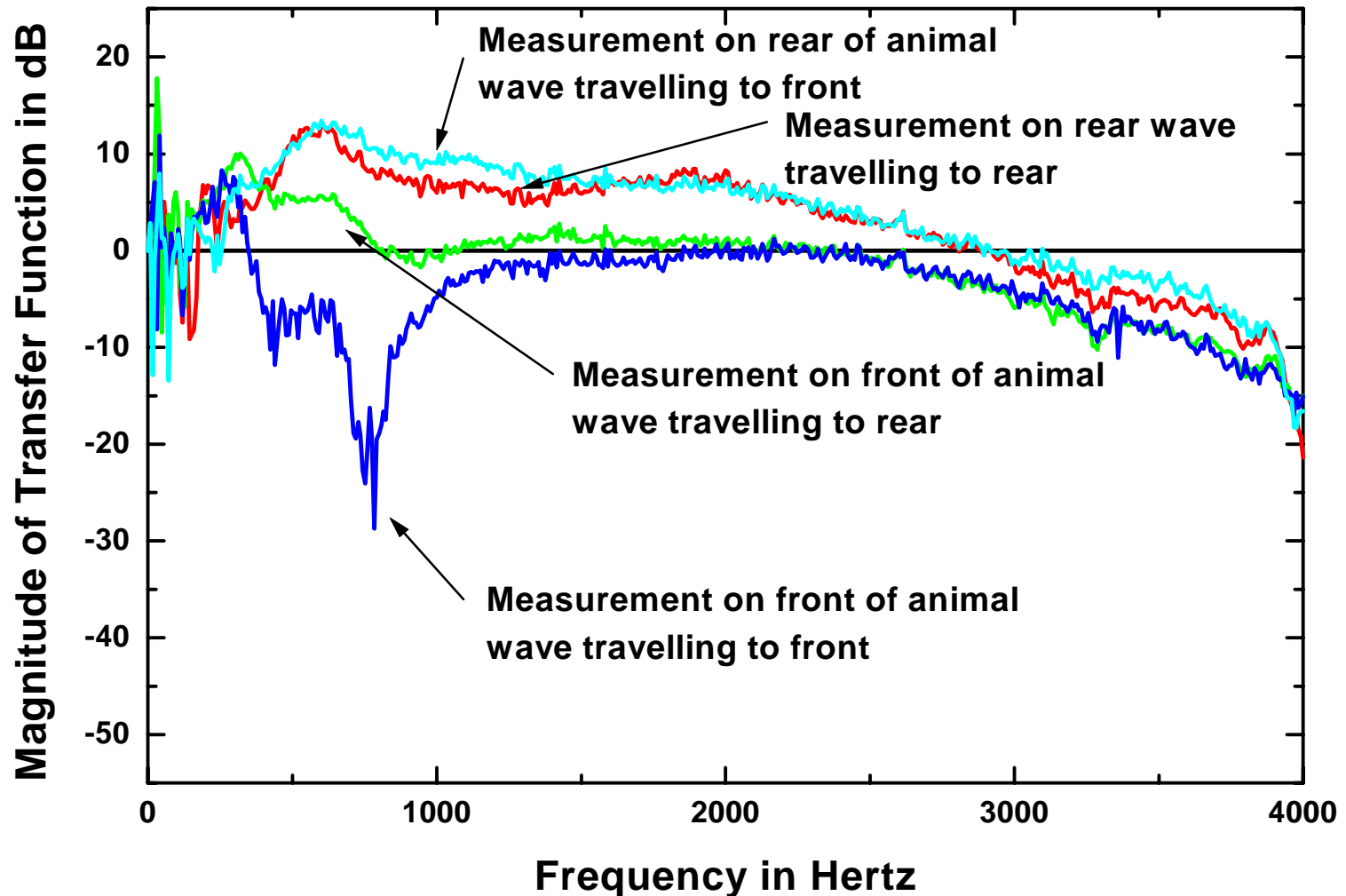
Vibrational Communication in a treehopper



Bending Wave Simulator



Vibration Depends on Wave Direction



Proposed Biomimetic Sensors

- Miniature acoustic particle velocity and pressure sensor for sound intensity measurement
 - Higher-order miniature directional microphones- Passive, low-cost
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References

- [1] R. N. Miles, D. Robert, and R. R. Hoy 1995 *Journal of the Acoustical Society of America* **98**, 3059-3070. Mechanically coupled ears for directional hearing in the parasitoid fly *Ormia ochracea*.
 - [2] D. Robert, R. N. Miles, and R. R. Hoy 1996 *Journal of Comparative Physiology* **179**, 29-44. Directional hearing by mechanical coupling in the parasitoid fly *Ormia ochracea*.
 - [3] R. N. Miles, T. D. Tieu, D. Robert and R. R. Hoy (1997), "A mechanical analysis of the novel ear of the parasitoid fly *Ormia ochracea*," in *Proceedings: Diversity in Auditory Mechanics*. E. R. Lewis, et. al. (Eds.), (World Scientific, Singapore), pp. 18-24.
 - [4] Robert, D., Miles, R. N. and Hoy, R. R. 1999 *The Journal of Experimental Biology* **202**, 1865-1876. Tympanal hearing in the sarcophagid parasitoid fly *Emblemasoma* sp.: the biomechanics of directional hearing.
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